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Comparison of manual and target controlled methods for minimal-flow anesthesia with a laryngeal mask

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Abstract

Aim: Distribution of fresh gas flow and anesthetic agent in low- and minimal-flow anesthesia can be sustained manually by the anesthesiologist or using automatic settings on devices with the target-controlled method selection. The target-controlled method is a gas delivery mode, which automatically sets the fresh gas, anesthetic agent and oxygen distribution system without requiring additional manual settings to reach the targeted levels determined by the anesthesiologist for inhalation agent and oxygen values on the device. The aim of our study was to assess whether the target-controlled method may be more easily and reliably used compared to the manual-controlled method for minimal-flow anesthesia administration with a laryngeal mask.

Material and Methods: Our study included 82 patients with general anesthesia administration using a laryngeal mask for inguinal surgery under elective conditions. For minimal-flow anesthesia, the target- and manual-controlled methods were compared in terms of duration to reach minimal alveolar concentration (MAC) value 1, inhalation agent stability, gas consumption and the number of device interventions to ensure and sustain anesthetic stability.

Results: Target-controlled anesthesia displayed less variability in expirium sevoflurane concentration compared to manual control. In the manual-controlled group, the duration to reach the targeted MAC was significantly shorter compared to the target-controlled group (77 s vs. 120 s, $p<0.001$). The manual-controlled method required more interventions to the device to sustain the targeted oxygen and anesthetic agent concentrations compared to the target-controlled method (8 vs. 2, $p<0.001$). There was no significant difference between the groups in terms of sevoflurane consumption.

Discussion: In our study, the target-controlled method ensured adequate and stable anesthesia for short-duration cases with laryngeal mask use. Due to the ease of application and reduced number of device interventions required, we think the use of low- and minimal-flow anesthesia methods can be expanded.

Keywords

Target Control, End-Tidal Control, Manual Control, Minimal Flow, Low Flow

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Introduction

The carrier gas amount in inhalation anesthesia determines the anesthesia rate, depth and consumption of inhaled gases [1]. Virtue [2] reported that the minimal flow, a type of low flow using a fresh gas flow of 0.5 L/min, was economic and safe. This method reduces the consumption of fresh anesthetic gases, thus, lowering costs, and with re-breathing it assists in preserving the temperature and humidity of inspiratory gas mixtures [1,3].

For low-flow anesthesia to provide safe and adequate anesthesia depth, it is necessary for anesthesiologists to continuously monitor patient follow-up parameters and to perform many interventions to the device. Some new-generation anesthesia devices have an advanced target-controlled (end-tidal control) gas delivery mode to make management of fresh gas flow and inhalation agents easier. In the target-controlled method, the device identifies the levels of oxygen and anesthetic gas concentrations in a sample of the exhalation gas mixture and performs automatic setting with the aim of reaching the targeted values. The anesthesiologist determines the target expirium oxygen percentage (EtO_2) and expirium anesthetic agent concentration (EtAA) according to the patient's needs and enters them into the anesthesia device. During the case, the anesthesia device monitors these parameters and automatically sets the gas distribution and total flow to obtain and preserve the targeted values. In the literature, studies comparing the target- and manual-controlled methods with endotracheal tube for airway showed the target-controlled method reduced the number of interventions to the device by the anesthesiologist to ensure safe anesthesia conditions [4-6].

The combination of low-flow anesthesia and laryngeal mask (LMA) was shown to involve a tolerable level of volume leaks due to the accurate insertion of the LMA and to provide safe anesthesia maintenance [7]. However, in the literature, we did not encounter any study about the use of the target-controlled method for anesthesia administration with LMA.

The hypothesis of our study is that the target-controlled method will be easier and more reliably applied compared to the manual-controlled method for minimal-flow anesthesia with LMA. To test our hypothesis, we aimed to compare these two methods using the same anesthesia device in terms of duration to reach target sevoflurane concentration, maintenance and adequacy of anesthetic depth and the number of device interventions to ensure stability.

Material and Methods

Our prospectively planned study was performed after receiving permission from Hitit University Faculty of Medicine Non-Interventional Research Ethics Committee (Date: 25.04.2019, No: 2019/135). The study included 82 patients with unilateral inguinal hernia surgery planned under elective conditions who provided written consent. Inclusion criteria were determined as American Society of Anesthesiologists (ASA) I-II physical risk status and age 18-75 years. Cases with chronic obstructive pulmonary disease, coronary artery disease, congestive heart failure, pronounced anemia, BMI >24 kg/cm^2, heavy cigarette consumption, and chronic alcohol intake were excluded from the study. For the study, a GE Aisys CarestationTM anesthesia workstation (GE Healthcare, Madison, WI, USA) allowing the use of minimal-flow anesthesia was used.

Patients taken to the operating room were randomly assigned to one of 2 groups as Group M (minimal flow with the manual method) and Group H (minimal flow with the target-controlled method) using an internet-based software program (Research Randomizer, http://www.randomizer.org/).

In addition to routine monitoring (ECG, non-invasive blood pressure, SpO_2), Entropy Easy Fit Sensor (Entropy™, GE Healthcare) monitoring was performed. Demographic data and vital signs were recorded. After registering the patient age and weight information into the anesthesia device, all cases were given preoxygenation for 3 min with 6 L/min 80% O_2 - 20% air with a face mask. Then induction was completed with 20 mg lidocaine, 2.5 mg/kg propofol and 1 µg/kg fentanyl and an I-gel LMA appropriate to the patient's weight was inserted. Patients with LMA not inserted due to patient or technical reasons were excluded from the study. Anesthesia maintenance was provided by an inhaled mixture comprising O_2, medical air and sevoflurane, and IV remifentanil infusion (0.05-0.1 µg/kg/min). The opioid infusion dose was set by targeting a 40-60 entropy value interval showing adequate anesthesia depth during the operation. Patients were ventilated in volume-controlled mode with tidal volume 7 mL/kg, respiration rate 12/min, and positive expirium end pressure (PEEP) 5 cmH_2O. $EtCO_2$ value was targeted as 30 - 40 mmHg, with end-tidal O_2 in the range of 35 - 40%.

Immediately after the LMA cycle connection in patients in Group M, total fresh gas flow (TGF) was set to 4 L/m, FiO_2 50%, and vaporizer sevoflurane concentration 4%. The opening time for anesthetic gas was accepted as the initial time, and the duration, until minimal alveolar concentration (MAC) reached 1, was recorded. When MAC 1 was reached, the flow was lowered to 0.5 L/min to begin minimal flow, with FiO_2 at 70% and sevoflurane concentration set to 5%. The necessary vaporizer settings and FiO_2 settings were made to ensure MAC was 0.9-1.1 and EtO_2 was 35 - 40%, and the number of device interventions was recorded.

For Group H patients, the EtAA concentration targeting the MAC 1 values calculated by the device according to patient age was chosen. Settings were TGF 4 L/min and EtO_2 40%. The duration to reach MAC 1 value was recorded and then flow was lowered to 0.5 L/min. The anesthesiologist intervened with the device to hold the MAC value between 0.9 – 1.1, and the number of interventions was recorded.

With 15 minutes until the end of the surgical procedure, the anesthetic gases were stopped in both groups and the flow rate continued at 0.5 L/min. When subdermal suturing began, remifentanil infusion was discontinued. In Group M, the washout process began with manual settings (flow 10 L/min, FiO_2 80%). In Group H, the washout process began with the end-tidal washout method, a feature of the target-controlled method (flow 10 L/min, FiO_2 80%). When spontaneous respiration began, manual respiration continued and the LMA was removed when adequate tidal volume formed.

In our study, follow-up parameters were the duration to reach MAC 1, the number of interventions to the device, awakening time (duration from initiation of washout to eye opening),

and gas consumption data obtained from the device (O_2, air, sevoflurane). Other follow-up parameters comprised heart rate (HR), mean arterial pressure (MAP), SpO_2, peak and mean airway pressure, compliance, FiO_2, fractionated expiratory oxygen concentration (FeO_2) and fractionated expiratory agent concentration (Fe agent) recorded in the 2nd, 5th, 10th, 15th and 30th minutes.

Patients with entropy value >60 in the intraoperative period were excluded from the study as sufficient anesthesia depth could not be induced. During follow-up, in case of balloon deflation and immobility due to leaks, the TGF rate was increased and the patient was excluded from the study. A fall of 25% or higher in MAP during the intraoperative and postoperative period was assessed as low hypotension. Patients with no response in spite of IV fluid support were administered 5 mg ephedrine IV. HR <50 beats/min was assessed as bradycardia and atropine 0.5 mg IV was administered. If complications like cough, hiccups, biting, desaturation, breath-holding and bronchospasm occurred, they were recorded and suitable interventions were made. Cases with operation duration exceeding 90 min were excluded from the study. Patients were monitored in terms of postoperative hemodynamic findings and complications in the recovery room.

Statistical analysis

In this study, statistical analyses were performed using the SPSS (Version 22.0, SPSS Inc., Chicago, IL, USA Hitit University License) program. Descriptive statistics are presented as mean ± standard deviation for continuous data with normal distribution, as median (min-max) for data without normal distribution and as numbers and percentages for categoric data. The normal distribution was investigated with the Kolmogorov-Smirnov and Shapiro-Wilk tests. When comparing the means from two independent sample groups for continuous variables, the independent groups t-test was used for data with a normal distribution and the Mann-Whitney U test for data without a normal distribution. Correlations between categoric variables were researched with the chi-square test or Fisher's exact test linked to the amount of data in the cross-tab cells. The statistical significance level was assessed as p <0.05.

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

Our study evaluated 111 patients for inclusion and was completed with 41 patients in two groups. The CONSORT flow diagram is presented in Figure 1.

In both groups, patient features and anesthesia durations were similar (Table 1). The duration to MAC 1 was 77 s in Group M and 120 s in Group H. The duration was significantly shorter in Group M (P <0.001). The maximum inspirium agent concentrations were 3.1 (2.1-3.9) in Group M and 2.7 (2.2-4.1) in Group H and this parameter was significantly high in Group M (P <0.05).

In-group assessment of expirium sevoflurane concentration found statistically significant differences in Group M at 2, 5, 10 and 15 minutes (P <0.001). In Group H, there were no significant differences (P =0.719). Comparisons between groups found significant differences in expirium sevoflurane concentrations in the 5th, 10th and 15th minutes (P 0.007, <0.001, <0.001,

Table 1. Comparison of patient characteristics and anesthesia durations.

		Group M (n = 41)	Group H (n = 41)	P value
Age		49.92 ± 14.05	50.07 ± 14.80	0.964[a]
Sex	Man	34 (82.9%)	38 (92.7%)	0,177[c]
	Woman	7 (17.1%)	3 (7.3%)	
ASA	I	20 (48.8%)	17 (41.5%)	0.506[c]
	II	21 (51.2%)	24 (58.5%)	
BMI		25.90 ± 3.24	25.97 ± 3.53	0.920[a]
Anesthesia duration (min)		51 (30 - 88)	50 (30 - 95)	0.525[b]
		53.26 ± 14.83	52.24 ± 16.17	

[a] Independent groups t test (mean ± SD), [b] Mann-Whitney U test (Median (min - max)), [c] Chi-square test (n (%))

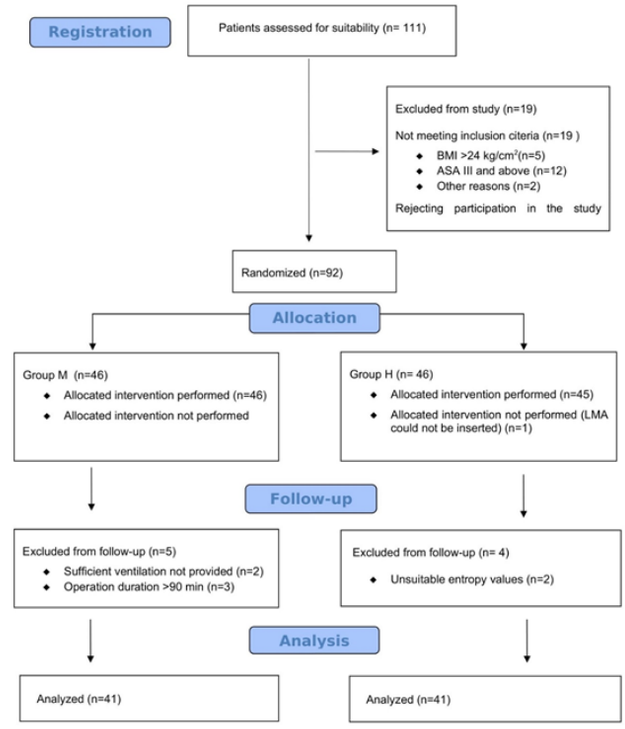

Figure 1. CONSORT flow diagram [8].

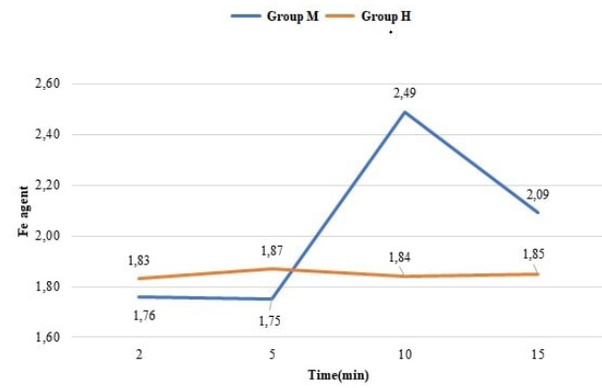

Figure 2. Variation in expirium sevoflurane concentrations over time.

Table 2. Comparison of gas consumption volumes.

	Group M	Group H	P value
Oxygen L/min	2.00 ± 0.74	2.40 ± 0.94	0.038[a*]
	1.95 (0.87 – 4.18)	2.37 (0.85 – 4.65)	
Air L/min	0.30 (0.18 – 0.82)	0.48 (0.20 – 1.88)	0.002[b*]
	0.39 ± 0.19	0.63 ± 0.41	
Sevoflurane mL/min	0.16 (0.11 – 0.52)	0.17 (0.11 – 0.33)	0.395[b]
	0.18 ± 0.07	0.18 ± 0.04	

[a] Independent groups t-test (mean ± SD) , [b] Mann-Whitney U test (Median (min - max))

respectively, Table 2). The variation in expirium sevoflurane concentrations in both groups over time is presented in Figure 2.

The number of interventions to the device to reach and sustain the targeted O_2 level and anesthetic agent concentration was 8 in Group M and 2 in Group H and the difference was statistically significant (P <0.001). The time to waking was 7.5 min in Group M and 6.9 min in Group H. There was no statistically significant difference in terms of waking durations between the groups (P =0.251).

In Group M, the oxygen and air consumption values were statistically significantly low compared to Group H (P <0.05, <0.01, respectively). In terms of sevoflurane consumption, there was no statistically significant difference between the groups (Table 2).

There were no statistically significant differences between the groups at all measurement times in terms of perioperative hemodynamic parameters, intraoperative airway pressure and complications.

Discussion

In our study comparing manual- and target-controlled methods for minimal flow administration with LMA, the target-controlled method provided a more stable anesthesia level. Additionally, the target-controlled method required less device interventions to reach and sustain the desired values.

In our study, the duration to reach MAC 1 in the manual-controlled group was significantly shorter compared to the target-controlled group (77 s vs. 120 s). In the literature, similar studies reported different results. A study by Potdar et al. [4] found that the duration to reach the targeted EtAA concentration of 1.5% was shorter in the target-controlled group (3 min vs. 13 min). Wetz et al. [2] found that the duration to reach the targeted EtAA concentration of 1.2-1.4% in minimal flow sevoflurane anesthesia was 275 s in the manual-controlled group and 178 s in the target-controlled group. The reason for the longer duration required to reach the targeted sevoflurane level with the manual method in these two studies may be the lack of use of high TGF at the start of inhalation anesthesia in their protocols. In our study protocol, we used high TGF initially to ensure adequate anesthesia depth for surgery in a shorter duration. In this process, maximum inspirium agent concentration values were 3.1% in Group M and 2.7% in Group H. In our study, the increase in maximum inspirium agent as a result of high TGF administration initially is consistent with the short duration to reach MAC 1 in the manual-controlled method. Especially for low flow anesthesia, manually controlled anesthesia requires constant monitoring and numerous adjustments to the gas dosage by the anesthetist [9]. The duration allocated for manual control of anesthetic agents and O_2 concentration may cause the anesthesiologist's attention to be distracted from the patient. As the target-controlled method requires less monitoring and interventions, the workload is reduced, as shown in many studies in the literature [2,4,9,10]. In our study, consistent with the literature, the manual-controlled method requires a higher number of interventions to preserve the targeted intervals compared to the target-controlled method.

In spite of the lower number of interventions in the target-controlled group in our study, the expirium sevoflurane concentration showed less variation over time compared to the manual-controlled method. The target-controlled method was observed to ensure more stable anesthetic agent concentration compared to the manual-controlled method. In a study by Wetz et al. [2], they reported more stable expirium anesthetic agent levels in the target-controlled group. With the manual-controlled method, they found that the deviation percentage from the targeted value for the sevoflurane concentration was significantly higher at all measurement times.

Consistent with similar studies in the literature, there was no statistical difference observed in terms of waking durations for the groups in our study [6,9,10]. The lack of difference in waking duration is thought to be a result of similar patient characteristics, the same type of surgery and anesthetic methods.

According to the working principle of the target-controlled method, a fixed cycle pressure is provided at the end of expiration in the manual respiration bag. If this pressure reduces, TGF is automatically increased in response. If adequate cycle pressure cannot be provided in spite of the TGF increase, the target-controlled method is automatically ended [11]. In our study, adequate tidal volume did not form due to leak during the case for 2 patients in the manual-controlled group. The flow rate was increased as the bellows did not function and these patients were excluded from the study. In the target-controlled group, there was no patient excluded from the study due to leaks. As the target-controlled method preserved cycle air pressure by increasing TGF, we think no air leak at levels to disrupt ventilation formed in Group H in our study. In our study, no complications were encountered related to the target-controlled method applied with the end-tidal control module.

In our study, there were no statistically significant differences between the groups in terms of sevoflurane consumption. When we compared fresh gas consumption, the manual-controlled group was found to have significantly lower O_2 and air consumption. The higher fresh gas consumption in the target-controlled method may be associated with the high TGF use initially and the short surgical duration. In a study by Wetz et al. [2] with similar results, they explained the substantially high sevoflurane consumption in the target-controlled method as a result of the target-controlled method's use of high TGF. They proposed that this difference in consumption may reduce with longer anesthesia durations. Additionally, during the first 15 minutes of anesthesia in their study, the target-controlled method was found to have significantly higher O_2 flow and

they reported that this difference between the groups showed a reducing tendency in advancing time intervals. Due to the saturation phase of the anesthetic agent (washout stage), the target-controlled method may not have an anesthetic agent and fresh gas savings at pronounced levels during short-duration surgeries. As the anesthesia duration lengthens, a variety of studies reported that the anesthetic agent savings obtained with the target-controlled method will increase [6,12]. Comparison of anesthetic agent consumption remains limited due to differences in anesthetic devices used, TGA amounts, targeted anesthetic agent concentration and protocols applied. One of the limitations of our study is that the comparison of anesthetic agent concentration or consumption information could only be assessed for a limited period of time between the groups because the mean surgical duration for cases in both groups was less than 1 hour. Another limitation is that the remifentanil dose administered was set according to intraoperative requirements and the dose received by each patient was different. However, all patients had adequate opioid dose set to keep entropy values in the 40-60 interval and attempts were made to minimize the effect of this dose difference on waking duration.

Conclusion

The main outcome of our study is that the target-controlled method may be safely used for minimal flow anesthesia in surgeries where LMA is chosen for airway control. Though the target-controlled method took longer to reach the desired sevoflurane concentration, it provided a more stable anesthetic agent concentration during inhalation anesthesia maintenance. Additionally, the target-controlled method required lower number of interventions to the device to sustain sevoflurane and EtO_2 concentrations in the desired intervals. This largely simplified minimal flow anesthesia management and positively contributed to the patient monitoring process by saving the anesthesiologist from performing tiring, time-consuming and distracting tasks.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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